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Limnological Evaluation of Artificial Development in Littoral Zone of Lake Kasumigaura, A Typical Maritime Lagoon Lake in Japan

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ABSTRACT

The structure and function of the littoral zone of a wide and shallow lake are two sides of the same coin. In the case of Lake Kasumigaura, a maritime lagoon lake, the second largest and a very important water resource in Japan, the base of the littoral zone is sandbar on which a surface layer of silt, mud, organic substances and Reed communities are formed. The littoral zone is about 1/100 gradient while the sandy shore is about 1/50. A sandy berm or ridge consisting of sand, organic debris, and garbage has formed a little back from the sandy shore. This sandy berm is mainly formed when substances washed up onto the littoral zone by high waves. Flat, stable *Phragmites-Carex* communities are found behind the sandy berm. The structure is ensured by the mutual relationship of wash up from the aquatic area and push out from the terrestrial area. The accumulation of piled silt, mud and organic debris in the littoral zone means that these substances are removed from the lake water. The littoral zone is a most indispensable area for water quality conservation in the ecosystem of a wide shallow lake. Without consideration on this important point, the littoral zone of Lake Kasumigaura has been mostly reclaimed and the water is enclosed by an embankment since about four decades ago. Such artificial development is very successful in water control, irrigation, agriculture and housing, and has contributed to the rapid economic growth in Ibaraki Prefecture and Japan. Also, since the dyke construction, no flood damage has occurred. However, we have experienced a huge loss in water quality conservation, biodiversity and fishery production. 12 former bathing beaches totally closed about 30 years ago due to water quality deterioration and drinking water is supplied from the lake water through a high-cost water purifying plant. Belatedly, though, thoughtful citizens have realized the function of the lost littoral zone of Lake Kasumigaura. We are facing a difficult problem of whether regeneration of the natural littoral zone is feasible or not.

Key words: lagoon lake, littoral zone, artificial development, water quality

INTRODUCTION

Lake Kasumigaura is a representative maritime lagoon lake located in Ibaraki Prefecture, Kanto basin, Japan. It is a typical wide and shallow lake (max.depth:7m, mean depth:4m, surface area:220km^2). It has 2157 km^2 of catchment area and 56 inflowing rivers. The water quality has deteriorated due to rapid eutrophication and desalination. Desalinated water due to the construction of a sea water barrier (Hitachigawa Water Gate, 1963), now provides a vital water resource utilized as agricultural irrigation water, industrial water and drinking water for the Ibaraki Prefecture and Tokyo metropolitan area. At the same time, the littoral zone is mostly reclaimed and a concrete dyke is constructed along most of the shore line. The lake has been completely enclosed by the dyke for the last four decades.

Recent values in water quality are approximately 7~8mg/l in COD(Mn), 0.1mg/l in total phosphorus, 1.0mg/l in total nitrogen. Water quality improvement is one of the important matters to be addressed not only by local residents using lake water as tap water and industrial water but also by local or national government and the people who live in the Tokyo Metropolitan area.

However, once water quality deteriorates in a big lake, improvement becomes a very difficult problem. Though many counter measures and a large budget has been utilized to this issue based on the statutes against eutrophication or pollution of the lake water over the last four decades by national and prefectural government, the water quality has remained at the eutrophicated level.

In recent years, the national government has launched a "nature rehabilitation project" in the littoral zone remaining in narrow confines in front of the dyke. This project was followed up by construction of artificial structures like many wave-breakers to protect the aquatic flora. These wave-breakers create severe problems in water quality improvement. We, the Lake Kasumigaura-conscious citizens are seeking essential nursing methods for the rehabilitation of the littoral zone through a scientific understanding of its function and structure in our wide and shallow lake.

METHODS & RESULTS

About one century ago, a diverse topography of wetlands was recorded in an accurate map drawn by

surveyors of the former Japanese Army. However now, about 10 percent (26.6 km^2) of the lake area including the wetlands has been lost due to reclamation and river & land improvement projects by the national government, especially after World War.

We investigated the remaining littoral zone including narrow sandy beaches and Reed fields in the wetlands (Fig. 1, Fig. 2). We found that the basis of the littoral zone is a sand bar on which silt, mud, organic substances are accumulated. The gradient of the littoral zone is about 1/100, but that of the narrow sandy beach including the shallow area is about 1/50 (Fig. 3). Of these structures, a small sandy berm or ridge consisting of organic debris, such as waterweeds, plant-seeds, fragmented Reed stems, driftwood or bamboo-stems, dead fish, garbage and also coarse sandy particles has formed a little back from the sandy shore due to strong waves accompanying seasonal temporary flooding. The strong waves wash up such substances from the lake water. The sandy berm is about 50-70cm above the usual water level. Near or on the sandy berm, drifted twigs of willow bud accumulate and grow, forming scrub. Annual plants, such as Smartweed or Knotweed (*Polygonaceae*) communities often form on or near the site.

Figure 1. A narrow sandy beach slightly remained in front of the dyke in Lake Kasumigaura

Figure 2. A berm formed by strong waves between sandy shore and Reed field in Lake Kasumigaura

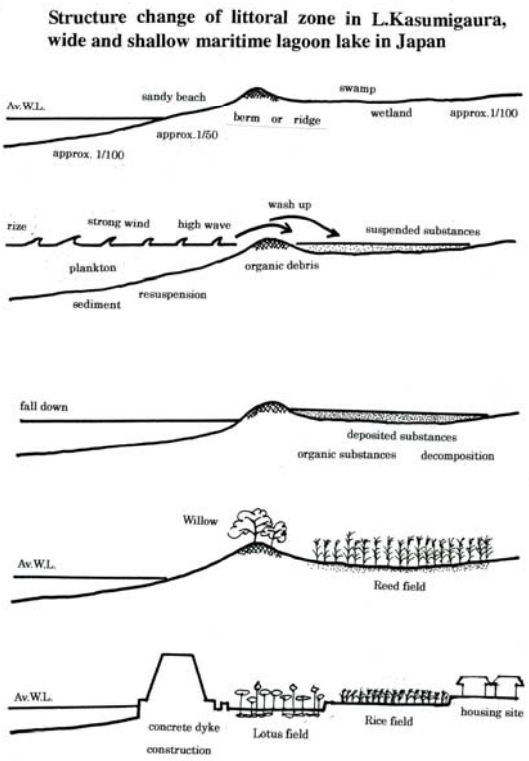

Figure 3. Structure change of littoral zone in Lake Kasumigaura, wide and shallow maritime lagoon lake in Japan.

Stable *Fragmites-Carex* communities form in the flat, wet backyard of the sandy berm. The bed of Reed fields is a sand bar covered with thick mud or the so-called gyttja layer which contains many organic constituents. Reeds usually grow, absorbing nutrient salts supplied from the decomposed organic debris. During flood seasons, the water level rises 50cm-70cm temporary in Lake Kasumigaura. The flood water intrudes into the Reed field over the sandy berm and contains phytoplankton and zooplankton. These accumulate in the Reed field where the lake water concentrates like a plankton soup accompanying the decrease in water level. The amount of plankton remaining in the Reed field decomposes gradually *on-situ.* The Reed roots absorb the inorganic nitrogen and phosphorous after the decomposition of the organic substances. Diatoms analysis often performed in similar muddy fields by other investigators are the good proof of this theory.

DISCUSSION

These facts undoubtedly point to the Reed field being formed as a result of the decomposition of organic substances. In the wide Reed field, the plant communities do not directly absorb nitrogen and phosphorous from the lake water. The lake water is

improved by removing organic substances in the littoral zone during the flood period accompanying strong winds and waves. The flat Reed bed is surely an indispensable site for decomposition and synthesis. Therefore, the gentle slope of littoral zone is a most important place in the ecosystem of a wide, shallow lake. In other words, the topography of the littoral zone itself has an automatic-water quality improving function or system, like the urinary system of an animal.

However, the dyke was improperly constructed right on the shoreline in Lake Kasumigaura. We, Japanese call such a dyke “Okidasi-tei” which means off-shore dyke. In those days, our senior fellows ought to have constructed “Hiki-tei” which means a dyke constructed in the terrestrial zone leaving the shoreline free. Unfortunately they had not done their homework on the function and structure of the littoral zone of a wide shallow lake like Lake Kasumigaura. There was no advice from limnologists. Needless to say, it was a difficult situation. The country suffered from a scarcity of food especially rice, a demand for expansion of Rice fields and Lotus fields and a shortage in the national budget to purchase private wetlands. What is done cannot be undone. However, we, at present, should learn valuable lessons from past mistakes.

Figure 4. Reclaimed wetlands are used as Lotus field and Rice field in Lake Kasumigaura

Development of the wide littoral zone of Lake Kasumigaura eventually brought fortune or prosperity to local and national society. Completion of the ”Lake Kasumigaura comprehensive development project”, contributed to rapid economic growth, especially for water control, reclamation for farmland and housing sites, convenient water use for agriculture, industry and drinking water. Since dyke construction, no flooding damage has occurred. At the same time, the former wet farmland around the lake has improved into arable fields with good drainage and productivity (Fig. 4). In addition, development of farm machinery has reduced the labor requirement. Lake water is transported to distant farmlands via pipelines. The systematic agriculture in this district has realized a stable rice production. We in our daily life and industry obviously received a benefit from the “Lake Kasumigaura Comprehensive Development Project”. This benefit has even reached the people who live in the Tokyo Metropolitan, consuming the agricultural products and water from Lake Kasumigaura District. To be fair, judging objectively, this national project has produced marvellous results.

On the other hand however, we have experienced a big loss in water quality conservation, ecosystem conservation and fishery production. Twelve bathing beaches were totally closed three decades ago due to water quality deterioration in particular eutrophication. Drinking water is supplied through a water purification plant run by Ibaraki Prefecture using high technology at an expensive cost performance. We are occasionally troubled by water blooms of blue-green algae, *Microcystis, Anabaena, Oscillatoria* etc. Artificial development cannot please everyone or every side of society.

Matter cycle model in wide and shallow maritime lagoon lake in plain is presented in Figure 5. In this model, in-flowing loads are mainly taken out from lake *via* five channels, i.e. out-flowing loads through out-flowing river, suspended substances washed up by waves, fishery products, water-weed removal and sedimentation. Of these, we have overlooked the second channel. Suspended substances are mainly silt, mud and organic debris, i.e. driftwood or bamboo pole, dead fish, fragmented Reed and other macrophytes or water weed, garbage, zooplankton and phytoplankton. A considerable amount of the organic substances are removed into littoral zone from lake water through this smart-washing up mechanism by seasonal flood and strong waves. These natural functions of the littoral zone contribute the water quality improvement in wide and shallow lake

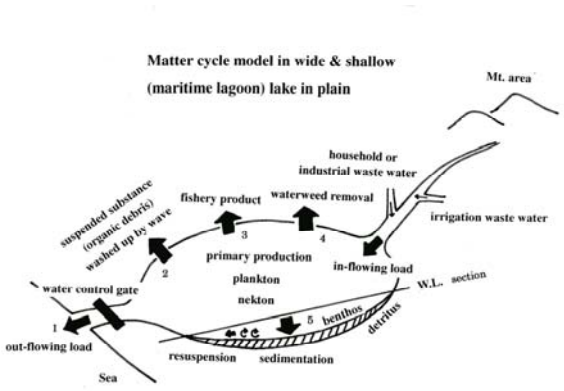

Figure 5. Matter cycle model in wide & shallow maritime lagoon lake in plain

We have finally noticed the importance of the lost littoral zone of this wide, shallow Lake

Kasumigaura. We have launched the “Nature Rehabilitation Project” through a council in which scientists, government officers and residents take part respectively under national statutes. However, the natural littoral zone has already been mosty suppressed. It is very difficult to expand the remaining narrow Reed fields or littoral zone in front of the dyke.

We have suggested nourishment of the sandy shore to local society and government. This sandy shore we hope will become popular with local residents, and also good for nature rehabilitation, especially Reed field expansion, breeding sites for the Reed Warbler, *Acrocephalus*, a spawning site for Smelt, *Hypomesus* and Icefish, *Salangichthys* in the shallow sandy bottom. In addition, as already mentioned, the littoral zone will add the function of water quality improvement. We, citizens have to maintain and manage on a daily basis the sandy shore by removing garbage and organic debris washed up by waves. We call such sandy shores “Sato-hama”. This means home beach or natural beach and both are familiar to residents and living organisms. Of course, rehabilitation of the littoral zone including the sandy shore and Reed fields in Lake Kasumigaura presents very difficult problem, and this is not helped due to shortage of governmental budget and lack of understanding from local residents.

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